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HOW TECHNOLOGY IMPROVES EFFICIEN-CY OF WAREHOUSES IN DIFFERENT IN-DUSTRIES

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Thesis Title: How Technology Improves Efficiency of Warehouses in Different Industries

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Abstract

This thesis study was done to point out the importance of the warehouse's role in the supply chain and to show how cost reductions can be achieved by using simple methods.

The objective of the thesis is to make clear that warehousing is a very important part in the supply chain and thus accruing costs may not be passed unheeded. Revealing that it is not needed to do large investments to reduce costs significantly so the return on investment will be high. Ultimately, it was revealed that the discussed methods are applicable to several industries and are thus independently usable.

The study's framework is based on reading and analyzing several text books, articles, and calculations for having a theoretical background for the empirical part.

The results in the practical part were company cases gathered from different industries. These were presented, analyzed and the calculations were made based on these information. Independent recommendations were made and the coherence between the analyzed methods was revealed.

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1 INTRODUCTION

The warehouse or any storage facility is part of the logistics management systems that belong to supply chain management and still play an immense role in it. How meaningful a warehouse is within the supply chain depends on the company and the company's business/structure. Mainly, the warehouse should be used as a trans-shipment point for received goods to dispatch as fast, effectively and efficiently as possible.

The issue is that many companies do not know or do not take the warehouse into account when searching for cost reduction potentials. Especially, when building and designing the warehouse efficiently from the very beginning, it will bring many benefits such as less costs and higher productivity.

In addition to that, some companies have even higher inventory than equity, which means that they keep dead stock and lead to lower growth. (Hennes & Metzger, 2008)

Here it becomes important for the managers to understand the different roles of warehouses, how these influence the business and the entire supply chain. (Richards, 2014, p. 2) Nowadays, the globalization competition has increased and thus the pressure enlarged on product availability, quality, time and reducing costs.

My thesis is focused on the methods which are used in warehouses to reduce costs and improve efficiency. The main focus will be put on the impact of implementing WMS, RFID technology and deploy voice picking. The particular focus on these methods was defined because there is a coherence of use between all of the methods. Through the combination of use, it is possible to leverage the improvements, thus high cost savings and many other benefits. The objective of the thesis is to show the technology's importance and its impact when used in warehouses.

By giving fundamental theoretical framework to give an understanding about the importance of the warehouse's role in the supply, I will reveal conclusive company case studies from different industries where the methods are used to

show that the methods are widely applicable. No matter what industry or company size is.

2 THE ROLE OF THE WAREHOUSE

Previously, warehouses were seen as cost centers and rarely adding value. However, with the intensification of international trade relations and growing globalization, the rising use of e-business and thus higher demands of customers, the warehouse was seen as an essential link within the supply chain. (Richards, 2014, p. 5)

Since it was understood that warehousing can cause high costs, an elementary understanding of inventory's impact on the income will enhance the ability to have the right goods, at right quantity and time in the correct place. (Muller, 2003, p. 19) The warehouse plays a big role in this scenario. The ability to deliver the right goods in the right quantity is based on picking and dispatching accurately in the warehouse. The products need to be labelled and loaded correctly onto right vehicle in a certain time to deliver the goods on time and to the right customer at correct place. It is also the job of the warehouse to make sure that the goods will leave it in an appropriate condition. All these tasks have to be done in a cost-efficient way to ensure customer's satisfaction. (Richards, 2014, p. 6)

2.1 Varying kinds of warehouse operation

A warehouse can have many different roles in the supply chain and inventory holding is only one among many. Hence, with the increased emphasis on moving goods, a lot of the roles can be related to the movement of goods and inventory holding. (Rushton, Croucher & Baker, 2011, p. 258)

The seven listed roles are only some of the common roles of warehouses performed, according to Rushton, Croucher & Baker (2011, pp. 258-259):

- *Inventory holding point.* Mainly linked to the decoupling point concept and can include the holding of substantial inventory. The holding of crit-

ical parts can also be a reason as well as being used as repository (e.g. for archive records).

- *Consolidation center.* Since customers' orders often include several items instead of only one and are to be delivered together, this type of warehouse will collect these items, from own inventory or from else-where in the supply chain, and fulfil the order towards customers' satis-faction.

- *Cross-dock center.* If the goods were brought elsewhere only to fulfil customer's order, the goods will be moved directly to the departing ve-hicle from the arriving without being stocked. This process is called *cross-docking*.

- *Sortation center.* Sortation centers are similar to cross-dock centers, but mostly used for parcel carrier depots. The goods are brought here for the purpose of sorting them to a specific region or customer.

- *Assembly facility.* This makes it possible to push production as far as possible downstream the supply chain. As a result, it is likely to save inventory costs and the warehouse takes the role of being the final as-sembly point for the product.

- *Trans-shipment point.* Used to serve outlying areas of a country e.g. the order is picked at a national distribution center, transported to a "stockless" trans-shipment depot and then the goods will be sorted to smaller vehicle loads for direct delivery to customers. In essence, trans-shipment depots are used for sortation purposes or draw-bar trailers are used to carry swap-bodies, which are ready for the local delivery. Hence, a local vehicle would only pick up a swap-body and deliver to customer.

- *Returned goods center.* Since recycling becomes more important as well as the increased internet shopping, the handling of returned goods will be increasing.

There are many warehouses which are not specifically one type; often they fulfil a mix of these different roles. (Rushton, Croucher & Baker, 2011, p. 228)

2.2 The importance of holding stock

Since it is not possible to forecast the markets and demand, it is necessary to keep stock at various stages. Due to the growing demand for higher product range, the storage capacity is uncertain. (Richards, 2014, p. 12)

Muller (2003, p. 3) describes a few motives to keep inventory:

Fluctuations in demand mean the demand is unforeseeable. Therefore inventory will be held as a protection to satisfy customers at any time with the availability of goods.

Predictability matters regarding capacity planning and production scheduling it is necessary to know how much raw material, parts, and subassemblies will be processed at a certain time lead to inventory buffers.

Quantity discounts are often reached by ordering in bulk.

Minimizing ordering costs: this motive can be connected with the *quantity discounts*, but basically means that an item will be ordered less frequently but in higher quantity. However, the costs for holding the large amounts of items exceed the cost savings.

2.3 Warehouse costs

According to Muller (2003, p. 2), the costs of a warehouse can include: Dollars, Space, Labor to receive, check quality, put away, retrieve, select, pack, ship, and account for. Additional cost drivers are deterioration, damage, obsolescence and theft are also cost drivers.

Referring to Rushton, Croucher & Baker (2011, p. 223), warehousing represents with approximately 20 to 30 per cent of logistics costs a significant sum for many companies. Only 18 to 20 per cent of these costs account to carrying the inventory. However, the costs differ from the company's operation and so it is not possible to make a breakdown that fits for all companies. Nonetheless, approximate figures can be given from past studies:

- Labor(mainly picking and packing) 45 to 50 per cent
- Space (rent & depreciation) 25 per cent

- Building services (heating, lighting, electricity, maintenance, insurance etc.) 15 per cent
- Equipment (rental or depreciation, maintenance and running costs) 10 to 15 per cent
- IT (systems & data terminals) 5 to 10 per cent.

Since the pressure is on mangers to reduce costs, while providing optimal customer service, it is vital to understand exactly what stands behind the costs and cost drivers in the warehouse. Additionally, reducing inventory but increasing the numbers of stock keeping units. (Richards, 2014, p. 276)

The various and typical types of cost within a warehouse can be found in Appendix 1.

3 WAREHOUSE OPERATION

The design of a warehouse is very important. It has to meet the specific needs in the supply chain, and specific operations are common in most warehouses. There is basically no difference whether it is manual in nature with basic equipment or high-technology equipped. Main processes for an inventory holding warehouse will be discussed below. (Rushton, Croucher & Baker, 2011, pp. 229-230)

3.1 Processes

According to Van den Berg (2007, pp. 60-61)warehouse processes are as follow:

Receiving includes unloading an incoming truck and identifying, registering and maybe repacking the products.

Putaway means to remove the incoming goods from the unloading dock to the storage.

Storage – Bulk and Pick is when items are in *storage* and activities can take place which affect the goods. For example, changing storage areas to optimize warehouse utilization.

Replenishing is the process of filling up the storage from a bulk if the inventory in the pick area is running low. Provided there are separate bulk and pick areas.

Pick, provided there are bulk and pick areas, means that full pallets are picked from bulk area and small quantities are *picked* out of the pick area.

Since it consumes most labor, order-*picking* has to be viewed as the most important process in most warehouses. Especially in low-volume distribution, e.g. service of spare parts, where mainly each order will be different, urgent and small, the order-*pickers* may have long distances to cover for each pick in addition the ways may differ from order to order. (Bartholdi & Hackman, 2008, p. 137) Here it is important to reduce the travel time to *pick* the goods. This is the biggest component of labour in a classical distribution center, but the travel does not add value and thus it needs to be mitigated. Additionally, the reduction of travel time improves customer service, so the faster the order is picked the faster it can be made ready for shipment. (Bartholdi & Hackman, 2008, p. 139)

The figure below shows the warehouse activities as a percentage of total cost. In this case, order picking accounts for approximately 35 per cent of total warehouse costs. In contrast, Frazelle (2001) reports that up to 50 per cent of the total warehouse operating costs accounting to order picking. However, Richards clarifies that this figure will differ expressively relating to the type of operation. Therefore companies that have to increase their throughput probably use concepts such as cross docking to reduce time spending on put-away, picking and retrieval. (Richards, 2014, p. 59)
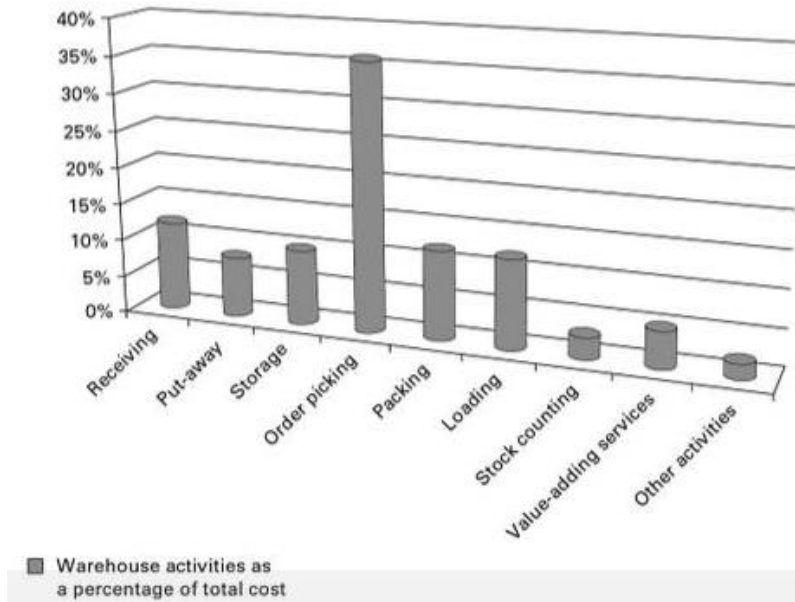
Figure 1: Warehousing activities as a percentage of total cost (Richards, 2014, p. 59)

Ship is the process of picking, packing, consolidating and staging a product for *shipping.* By terminating this process, the product will be loaded onto a truck for the departure.

Cross-dock describes the activity for goods which are directly after receipt *cross-docked* to a shipping dock instead of putaway into storage.

Value Added Logistics is offered sometimes by distribution centers which can be country-specific labelling or packaging.

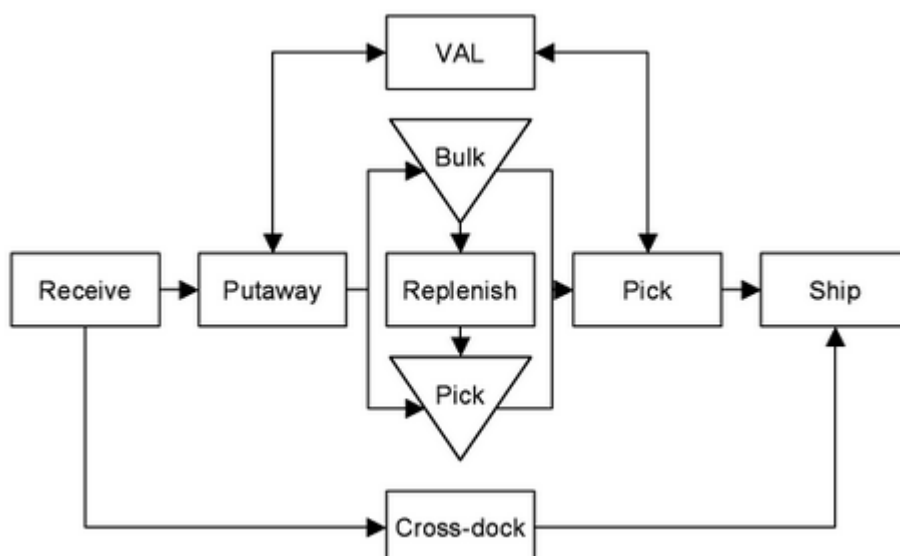This picture visualizes the processes and coherent flows mentioned above;

Figure 2: Processes and flows in a distribution center (Van Den Berg, 2007, p. 60)

3.2 Methods to reduce costs

This chapter will include the examination of some methods/strategies to reduce costs and increase warehouse efficiency. The focus will be on the three challenges revealed in the figure below.
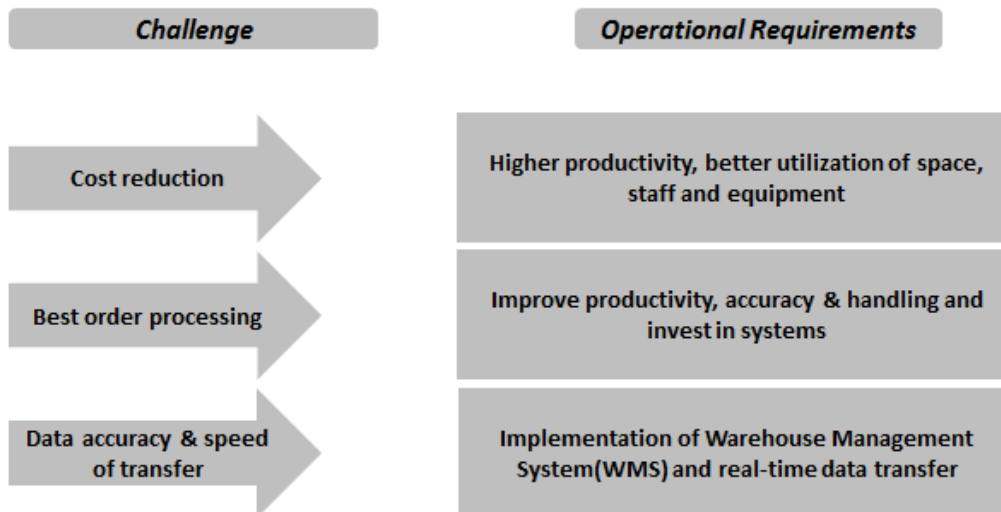

Figure 3: Challenges in warehouses adapted from (Richards, 2014, p. 44)

3.2.1 Pick Preparation

Due to the fact that picking is the most costly activity within warehouses today, it has the highest overall saving potential of all warehouse activities. Causes for the high costs originating from labor intensity and challenged automation can lead to difficulties in planning, vulnerable for error appearances and directly impact customer service. Characteristically, errors are related to wrong amount of picked items; items that were forgotten to pick or wrong items. The picking area is targeted by the companies as the area where productivity improvements can lead to significantly different overall costs. Consequently, the target conflict here is between cost, accuracy and speed, but the focus of managers is often different. They look for high responsiveness, accuracy and productivity but not cost. In order to satisfy these factors, it was mandatory to evaluate an appropriate system, according to individual needs. The picture below shows the interrelationships of picking, but also labor, technology, equipment and warehouse layout. (Richards, 2014, pp. 77-78)
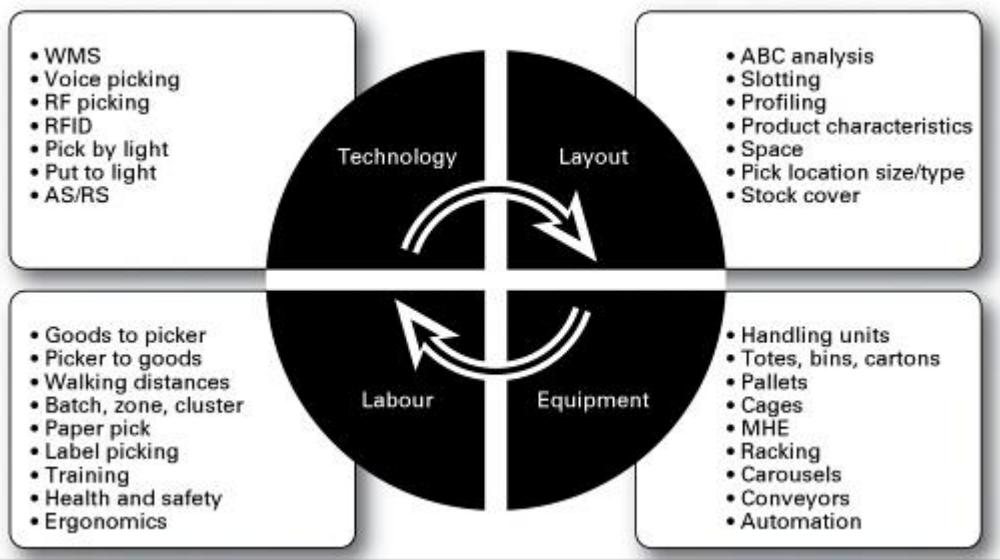
Figure 4: Picking interrelationships (Richards, 2014, p. 78)

Therefor the preparation for the picking process is the key element for improvements. Richards also (2014, p. 79) explains that more than 85 per cent of SKUs in a warehouse are not assigned to the most efficient location, leading to a 10 to 30 per cent increase of travel time and underutilization in different location.

Important steps towards a well-prepared picking area are as follows, according to Richards (2014, p. 79):

- Laying out a warehouse
- Deciding of most appropriate handling equipment tools
- Installing storage systems & according to that decision of initializing a picking system
- Full ABC-Analysis of stock movements and stock held

However, referring to (Fachverlag für Marketing und Trendinformationen, 2007) there are two separate types of analysis pursuing the same target: one for stock movements (XYZ-Analysis) and the other one for stock held related to value (ABC-Analysis).

The target of an ABC-Analysis is to determine the value of the products to turnover. The analysis is based on Pareto's Law or the 80/20 rule that means that roughly 80 per cent of effects come from 20 per cent of causes. (Richards, 2014, p. 79) Regarding this, the goods in the warehouse have to be

analyzed and categorized into "A", "B" or "C" goods. "A" goods are the most important goods by producing 80 per cent of the sales with 20 per cent of the products. Second are "B" goods, which make approximately 35 per cent of goods with sales of 15 per cent. Least important goods are "C" goods that produce approximately 5 per cent sales with 45 per cent of products. (Richards, 2014, p. 80) Finally, analyzing the items and defining instructions for each category.

The XYZ-Analysis is categorized by (Fachverlag für Marketing und Trendinformationen, 2007) as follows: X-Goods are characterized by their constant and highly predictable demand, Y-Goods are medium frequently sold and Z-Goods' demand is completely erratic and unpredictable. Also, here analysis needs to be done for each category and instructions defined depending on company's aim.

The figure below shows the instructions after combining both analyses;
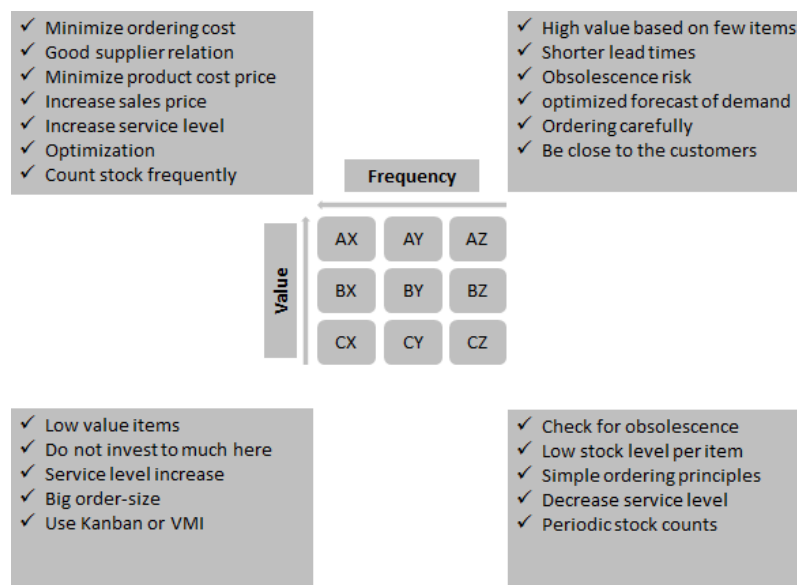

Figure 5: ABC-XYZ Analysis adapted to (Richards, 2014, p. 83)

The XYZ analysis can also be adapted to different criteria. The following example refers to the control over the highest stocked item regarding its stock value. (A comprehensive guide on Materials Management)

Therefore, the different items have to be applied to different categories which are defined through "scoring" the inventory item according to annual stock value. Hence, the classification results that X class items represent 70 per

cent of stock value, Y class items fall between 70 and 90 per cent of annual stock value and C class the remaining. (A comprehensive guide on Materials Management)

However, not all stock is equally valuable and the results of this analysis help to determine the type of inventory requires more monitoring and controlling. Resulting actions of the analysis are, according to A comprehensive guide on Materials Management, as follows:

X class items, although they cover only a small part of overall inventory, need to be well-monitored and tightly controlled.

Y class items do not require so much control or monitoring but periodic reviews of usage.

Z class items oblige the least control and may have issues such as "free stock" or forward holding.

This classification can be the basis for different strategic activities, based on (A comprehensive guide on Materials Management), such as:

- Alternative stocking arrangements
- Reorder calculations
- Frequency of inventory checks

Regarding the frequency of inventory checks, X items have to be checked more frequently than Z items. (A comprehensive guide on Materials Management)

3.2.2 Picking methods

Referring to Palevich (2012, p. 36) picking can be the most labor-intensive activity in the warehouse, which leads to the figure of approximately 75 per cent of time spent in activities, associated to picking. This examination with value stream mapping (VSM) reveals that 75 per cent (10 per cent searching, 5 per

cent writing and 60 per cent walking) are non-value-added activities and only 25 per cent, which come from picking, are value-added.

Richards (2014, p. 138) lists the current methods of picking as follows:

Pick by lists, pick by label, pick by voice, barcode scanning, radio frequency identification (RFID), pick by light/pick to light, put to light and automated picking.

What method suits best for company's operation hardly depends on the type of operation the company is having. Product characteristics, total number of transactions/orders, picks per order, amount per pick, picks per SKU, total number of SKUs, value added processing e.g. private labelling, the form of pick (case pick, piece pick or full-pallet loads) are the factors that will influence the decision of choosing a suitable picking method. Often picking methods have to be combined in order to handle diverse product an order characteristics. (Piasecki)

Main goals of designing an order picking operation are increased productivity, reduced cycle time and increased accuracy, which many times may conflict with one another. (Piasecki) Therefore, choosing the correct picking operation can lead to significant cost reduction. As mentioned above, the largest producer of non-value-added is walking. For example, by decreasing this number by 30 per cent, efficiency is increased from 25 up to 31.25 per cent: 25/ (10 + 5 + 25 + 40) = 31.25 per cent. This means that the overall picking process gained 25 per cent in efficiency, which means in terms of labor a reduction of 25 per cent. (Palevich, 2012, p. 36)

3.2.2.1 Pick by voice

Pick by voice is gaining ground in warehouses internationally, mainly for order picking, but also for other processes such as cycle counting, put-away and replenishment. Many companies tend to change directly from paper picking to voice picking. (Richards, 2014, p. 139) The enhancement of the implementation can be measured with the key performance indicators such as orders

picked per hour per worker, lines picked per hour per worker, productivity improvement and cost per order. (Palevich, 2012, pp. 34-35)

Voice picking is a method of performing order selection in a warehouse or distribution center. (Flanders, 2002) The operators usually wear headsets with microphones additionally a small terminal attached to a belt or worn on the wrist. The warehouse management system sends messages to the computer via radio frequency transmissions, utilizing transmitters installed throughout the warehouse, so the messages will be converted to computerized-voice-instructions. (Richards, 2014, p. 140) Hence, the operators communicate with a software system in real time. This system provides the operator with picking tasks and the operator has to confirm after fulfilling them. Therefore the computerized voice gives commands to the operator to a pick location and confirming the location will be done by speaking the random check digits that appear on a label positioned at each pick location. (Phelan Jr., 2011)

As mentioned above, voice picking relies on voice instructions through headphones, microphone and the small terminal attached to the waist, which transmits via radio frequency (RF). (Emmett, 2005, p. 143) These headsets are one-ear headsets so that the operator can focus on potential safety hazards. Even personalizing the system according to foreign languages or accents is possible. Different systems meet different warehouses' needs. A speaker-independent system is a system that understands only a few words or numbers. However, the speaker-dependent system provides a greater complexity, vocabulary, and new technologies allow reprogramming and personalizing for each user. (Donath, Mazel, Dubin & Patterson, 2002, p. 297)

Additionally, this system does not require any long training or personalization. The training takes approximately fifteen minutes on average and is intuitive. Thus, training is tremendously faster compared to screen-based solutions. These systems are commonly used in establishments usually operating at 90 dB to 95 dB, which is equivalent to having a lawnmower around. (Donath, Mazel, Dubin & Patterson, 2002, p. 297)

3.2.2.2 Pick by vision

The following topic will be discussed briefly because it is in its early development stage.

Pick-by-Vision is still in the development stage and in the late field-test phase. There are different AR (Augmented Reality) systems such as head-mounted display (HMD), cameras, a wearable PC, and battery packs providing energy for minimum one working shift. This software can read barcodes, recognize real-time objects, navigate indoors and seamlessly integrate information with the WMS. (Glockner, Jannek, Mahn & Theis, 2014, p. 13)This means that information is provided without paper. Nevertheless, pick by vision systems provide the user with situation-dependent and perspectively correct virtual information in the field of view. The operators are equipped with data glasses that display all necessary information such as shelf, quantity and item code, even product images and can be visually led through the warehouse to the needed place. (f+h Intralogistics , 2013)

In order to reduce errors, intuitive information display and stepwise order filling process are crucial requirements for the system. This system can also be upgraded with camera integration into the data glasses to use video processing software. The software supports the operator actively in avoiding mistakes, which will be illustrated in the picture below. Thus, when an item is being picked, it is shortly held in the field of camera's view to scan an optical code and thus the operator receives information if it is the correct item or not. Great benefit in pick by vision is that the operator works hands-free. (f+h Intralogistics , 2013)
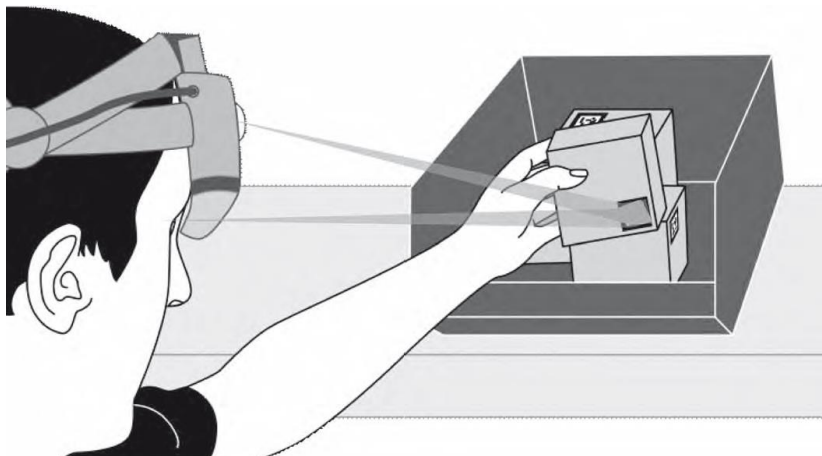

Figure 6: Pick-by-Vision data glasses with integrated camera (f+h Intralogistics , 2013)

3.2.2.3 Warehouse Management System (WMS)

In this chapter, I will discuss the implementation of a warehouse management system and show the coherence to Pick-by-Voice and also the additional benefit when using RF & Radio Frequency Identity Tags (RFID) with a WMS.

Very beneficial is that a warehouse management system can comprehend all handling activities in a warehouse such as generating pick lists, receiving stock with receipt documentation and put away labels, retrieving stock for pick faces, replenishing and pick faces. Consequently, the WMS leads to enhanced stock control, traceability, productivity-levels, and improved management reporting. (Emmett, 2005, p. 135)

Here are some possible WMS characteristics related to activities: the receiving activity can be enhanced by an automatic scanning process without any papers. For the put away or storage process, the warehouse management system can automatically generate the most suitable locations to reduce wasting space. As for picking, it provides the operators e.g. with real time pick confirmation, product release prioritization, batch and/or wave pick selection, automated replenishment activation. The activity dispatching can be influenced by e.g. appropriate road planning and sequencing, automatic checking by scanning paperless. (Emmett, 2005, p. 135)

In other words, a WMS is a key part in the supply chain with the goal of controlling the movement and storage of materials within a warehouse. As mentioned above, it is also cognizant of the picking operations since it directs the picker to place the item in a particular warehouse bin in close proximity and optimum location. This is included in the ABC-XYZ analysis, in which the commodity needed most is placed in the middle of the bin for faster picking or receiving, which is discussed in detail in chapter 3.2.1. (Palevich, 2012, pp. 27-28) Additionally, it outputs different metrics to evaluate for example the order accuracy which describes the accuracy with which the picker picks the order to be delivered to the customer. Hereby RF and WMS work well together to keep the accuracy very high. (Palevich, 2012, p. 32) Furthermore, it provides a computerized schedule, which helps the operators through their tasks by setting up the procedures and the appropriate times for every operation

performance. There is also the function to capture data for the ERP system e.g. tracking employee's performance, which opens new opportunities for managers to plan which operation the operator performs best. Also, it deals with the question: What schedule suits the workers best to minimize the distance traveled? It is very important to link the WMS with the Inventory Management System to monitor the product movements immediately and associate to the ordering system. These operations have to be as close as possible to real time to lower inventory levels and thus save money. (Palevich, 2012, pp. 28-29)

Thus, the use of a warehouse management system can bring these advantages:

Decreased labor hours by 40 to 50 per cent and with RF even 50 to 60 per cent. The computer measures the efficiency and the flow of the worker to match the worker to the job. As known, a typical warehouse worker has to walk large distances; approximately six miles a day, to fulfill the orders, and minimizing this will lead to remarkable increase in labor efficiency. (Palevich, 2012, pp. 36-37)

Inventory write-off decreases by five per cent, which is caused by an increased real-time tracking of inventory so that no goods are lost in the system. It also monitors the shelf life as well as it reduces mis-ships. Due to the fact that the system provides a faster tracking of inbound receipts to the stocking area, the total inventory drops by five per cent. The overstock locations are so reduced that it takes less time to split orders into stocking and overstock. An enhancement in space utilization is also produced by the WMS, which is designed to minimize the distance traveled thus simulating a smaller distribution center. (Palevich, 2012, p. 37)

Since the system is double checking with the RF system, which will be discussed in further detail later, the shipping errors were reduced by 80 per cent. Shipping errors and customer returns are anywise interrelated. In addition, the customer returns were reduced by 11 to 25 per cent due to fewer picking errors. (Palevich, 2012, p. 37)

The increased productivity of 16 to 25 per cent is only reachable with the use of a fully computerized and real-time system which measures against the needed metrics e.g. optimized picking routes. (Palevich, 2012, p. 37)

Radio Frequency in a WMS

The conventional Bar Code reading method is done by either fixed 'pass by' readers or by manual hand gun readers. Increasingly, these manual hand guns are being replaced by finger scanners which carry out equal procedures but more efficiently due to hands-free operations. The scanner works by finger pointing with the reader screen which is attached to the forearm. Communicating via radio frequency, the hands-free wearable scanners pass data to the WMS system which can communicate back with information on the next work cycle. (Emmett, 2005, pp. 142-143)

Hence, basically it is an extension of the WMS which is used for receiving, storage, and physically counting inventory that is enhanced by entering the counts in the system by the terminal to make the warehouse management process paperless. No matter if weekly or monthly physical counts were performed, the inventory cycles of the RF system work continuously. Enhanced productivity is promised by eliminating the warehouse downtime because no physical counts are required due to tracking inventory automatically in the system. (Palevich, 2012, p. 38) In the receiving process, this can mean that in case of having central stock an item is received but the system determines that there is already too much merchandise in stock, and runs through other warehouses to check if the item is needed elsewhere. In case it is needed elsewhere, the system will direct the cartons or pallets to be transshipped to a new warehouse location. Therefor the storing and repulling process is saved. If a received item is at a wrong location, the system sends a notification which indicates that the item is situated in the wrong warehouse. This mitigates errors in receiving and stocking to a minimum. (Palevich, 2012, p. 44) The RF broadens the WMS capabilities by enabling and improving the times and error rates, because entering a number is a seamless task, for many functions in distribution (Palevich, 2012, p. 39) and I will list a few:

For *unloading and staging goods* on the receiving area, it is very convenient to use an RF hand-held gun because this is the process of receiving and checking the delivered goods against the POs (Purchase Orders). The product will be brought into the storage area after staging it on the receiving floor. (Palevich, 2012, p. 39)

Sorting takes place after the product has been checked and staged. The goods are sorted out by warehouse location numbers and this is the longest process in receiving activity. First, the pallets are scanned with an RF device to separate the pallets by the appropriate RF locations. According to the WMS, each pallet will be moved to a different warehouse location and after placing the pallet in the stocking area to store the goods in close proximity. The goods can be license-plated with a bar code informing the computer that the specific item is located on the pallet. (Palevich, 2012, p. 39)

RF helps facilitate *creating the carrier identification file.* All data regarding inbound and outbound shipments by carrier are tracked in this file. The specifics for tracking the shipments by scanning are as follows:

- Storing shipment date
- Recording delivery time discloses punctuality of suppliers
- Saves loading and unloading time of employees for performance levels. (Palevich, 2012, p. 39)

Minimizing errors were accomplished by time reductions in writing the adjustments on forms and these forms could also be scanned and integrated in the system by RF or RFID system. (Palevich, 2012, p. 40)

Also, by standardizing documents such as the bill of lading, it eases supplier giving the information in the same sequence thus mitigating mistakes. It will also increase the pace of the receiving process because every form has the same appearance and this efficiency will draw through the entire supply chain for the product: from supplier over carrier and distributor to customer. (Palevich, 2012, p. 40)

The table below, given by O'Neil (2006), explains what actions companies should take according to their maturity levels across the different areas of an extended warehouse management.

Table 1: Competitive Framework for Extended Warehouse Management (O'Neil, 2006)

	Laggards	Industry Average	Best in Class
Knowledge	Limited visibility of order status from warehouse. None from manufacturing around extended facility	Daily visibility of order status, inventory, and commitments across the multiple warehousing space environments.	Real-time visibil-ity of order sta-tus, inventory, and commitments across multiple ware-housing envi-ronments the warehousing space as well as in transit activity
Dock and Yard Management Technology	Spreadsheets/clip-boards are prevalent	YMS is legacy, supports some initiatives. Some integration Homegrown, custom applica-tions with limited integration with WMS	Commercial software, including web-based appsapplications. YMS Dock and yard management systems have extensive has integration with WMS. Automated systems throughout extended warehouse environment
Performance Metrics	Trucks on dock longer-turned around in 5 hours or more (from yard in to yard out) than 6 hours Don't quantify important KPIs	Trucks turned around in stay on dock for 4-6 3-4 hours KPIs tracked but no room for more	Trucks on dock forturned around in under four two hours or less KPIs tracked and consistently up-dated

Actions can be for "Laggards" to move away from spreadsheets in yard and dock management and to move to automated systems. Automated systems give also the basis for future implementations. (O'Neil, 2006)

Steps for the "Industry Average" can be for example to use more technology advancements as automated distribution order management, visibility. (O'Neil, 2006)

The "Best in Class" companies should be looking for more innovations in warehouse process and particularly focus on the interaction between transpor-tation, dock appointment scheduling, and warehouse labor and dock capacity. (O'Neil, 2006)

3.2.2.4 Radio Frequency Identification (RFID)

In this chapter, I will discuss the use and cost of RFID in warehouses and slightly compare it to conventional barcode systems. Also, examples of use in different industries will be shown.

RFID can have highly positive impact on company's performance, but there must be a specific need for it since this solution does not suit all companies.

(Palevich, 2012, p. 49) This automatic identification technology allows to track and trace in various logistics applications. Indeed, barcode systems are most commonly used because of the simple structure, low cost and good standards. However, RFID is gaining in importance, however, because it offers additional benefits compared to barcode systems. (ten Hompel & Schmidt, 2007, p. 214) For example, it makes possible to read multiple items simultaneously whereas barcodes read individually. (Richards, 2014, p. 151) *"With a barcode scan, you have a one-to-one relationship, but with RFID you can have a one-to-many relationship, and that's where you see a significant increase in efficiencies. Instead of having to touch each item one at a time, RFID basically throws an umbrella of energy around an area or a box and detects everything in it."* L. Allen Bennett, CEO and President Entigral Systems, Greensboro, North Carolina (Motorola Solutions, Inc., 2011).

There are different sorts of RFID, which differ in being active or passive. The passive RFID tags have limited data storage capacity, limited read range, can only be read, and have no power source. Active tags have their own power source, greater data storage capacity, can be read, and written, and reached from a greater distance. Thus, passive tags keep only a little amount of data to identify an item and send the information to a database where additional data is stored. The active tags have a greater capacity and enable to update the item's status straight after a task has been completed. Their reading range is higher than writing range and the internal power source burns out in approximately five to ten years. An important factor is the frequency for transmission range and speed, but not all frequencies are available for a global use. (Richards, 2014, p. 151) An example of common frequencies used in Europe with explaining the difference between active and passive tags, will be shown in the table below.

Table 2: RFID Frequencies ranges in Europe (ten Hompel & Schmidt, 2007, p. 217)

Frequency range	Transponder type	Coverage
125 - 135 kHz (LF)	Passive	Some cm up to 1 m
13,56 MHz (HF)	Passive	Up to 1 m
433 - 868 MHz (UHF)	Active	Several m
2,45 GHz (Microwave)	Active	Up to several hundred m

Accordingly, the frequencies are classified in Low, High and Ultra High Frequencies as is illustrated in the table above with LF, UF, and UHF. LF is used for scanning goods close at hand and is also for access control, livestock, and race times e.g. triathlon. HF tags have a greater range than the LF tags and are generally used in smart tags for books and smart shelves tags. UHF with a range from 860 to 960 MHz is used in the supply chain processes. (Palevich, 2012, p. 39) Furthermore, Palevich (2012, p. 50) adds one more classification with a range from 2. 45 GHz to 5. 8 GHz and classifies these also as UHF. He points out that the 2. 4 GHz frequency is mainly used for the toll road I-Pass. The picture below shows the different frequencies used in the world. However, each region has the same frequency ranges in terms of LF.
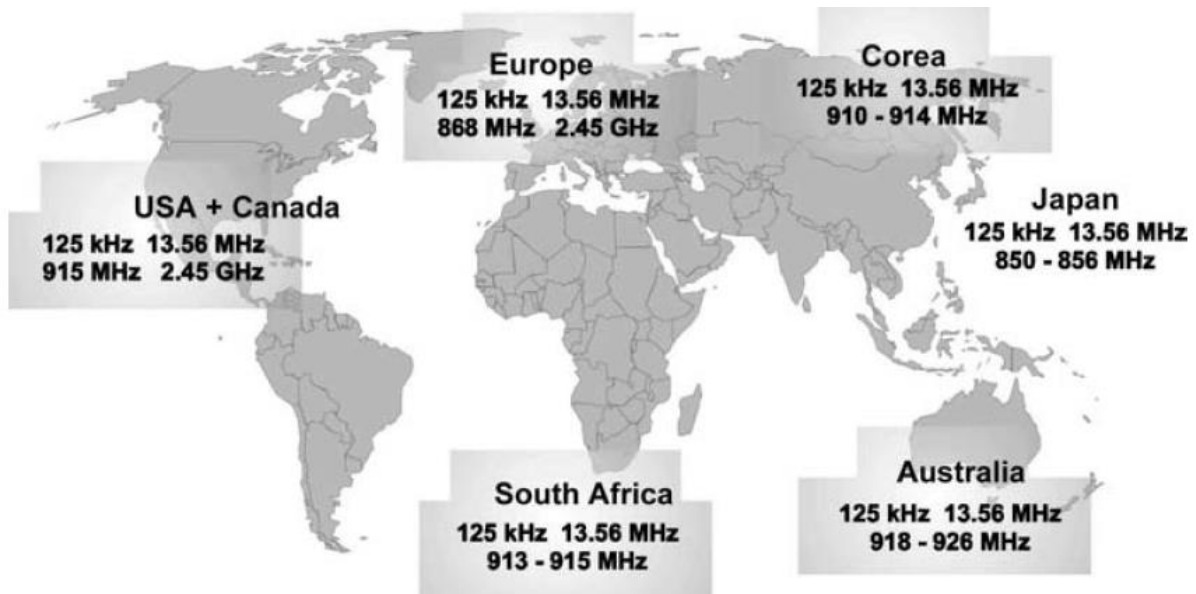
Figure 7: RFID Frequency ranges worldwide (ten Hompel & Schmidt, 2007, p. 218)

In terms of costs, RFID loses in comparison to barcodes because barcodes can cost a fraction of a cent or a few pennies, whereas RFID tags cost range from $0. 10 to $4 per passive tag. The active tags are tremendously more expensive, from $5 to $50, and their price highly depends on the functionality of the tag itself. (Russel, 2010) The following accessories are needed to implement an RFID system: RFID tags, reader, printer, antennas and cabling and middleware. The subsequent cost breakdown for an RFID system is based on a solution with a frequency of 900MHz RFID. (Palevich, 2012, p. 50) As the price for the tags is already mentioned above, I will not take the tags into account anymore. Therefore, the RFID reader usually costs between $1.200 and

$3.000 but the price also depends on the vendor and type used. Hand-held reader is generally more expensive. A printer, with which the labels are printed with readable data and an RFID tag, starts from $1.500 and reaches up to $4.000 and even above. Each antenna combination costs between $125 and $300 and cost additional $50 for cabling. The middleware is the major cost driver with $6.000 to $300.000 or more. The more complex the system should be, the more expensive it becomes and therefore specialized IT staff is required for installation. (Palevich, 2012, p. 50) The ROI is estimated from three to four months. (Palevich, 2012, p. 53)

However, the high cost for the tags compile because the RFID system is based on an EPC (Electronic Product Code) and not an UPC (Universal Product Code). (Palevich, 2012, p. 51) Thus, the tags are longer lasting and harder to copy or replicate, which provides more security. (Russel, 2010) Therefor, an EPC has four fields for a 96-bit tag and the first 8-bit (header) determines the tag's basic characteristics. Hence, if the tag is for example an item, location, asset tag. The next 28-bit is the EPC Manager, which indicates the supplier the item belongs to. The third field indicates with 24-bit if it is the item SKU or the UPC. The last 36-bit make the item unique e.g. with a unique serial number. (Palevich, 2012, p. 51)

4   CASE STUDY ANALYSIS

Companies that have been able to lower their warehousing costs by more than 10 per cent since 2004 are the top cost performers. These companies, 25 per cent of all companies, were only able to reduce costs due to particular actions, according to O'Neil (2006), such as:

- Sharing and capturing extended warehouse metrics in real time
- Using new generation of technology by continuously updating the warehouse technology infrastructure. Hence, service oriented software is easier to integrate, reconfigure and the company can use these advantages.

Thus, when using technology nowadays it becomes more and more important to reduce costs and the following part will support the increasing need of using technologies to save costs and be more efficient.

4.1 Pick-by-Voice

First of all, I will reveal an investment example which shows the changeover from Mobile Data Capturing (MDC) and paper based order picking to Pick-by-Voice with Dictulus. Here it is clearly seen that the ROI (Return On Investment) is very high. The additional travel time and distances were not taken into account in this calculation. Also were not considered possibly redundant forklifts and all amounts are presented net in euros. (Jauernig)

Firstly, the amount of investing capital is shown. It is determined by, among others, 19 pieces of Dictulus, System integrator License. The System integrator License is a fix investment which is not affected by the number of Dictulus. The same applies to the System house and other expenses. This includes e.g. the costs for implementation of Access Points by an IT company or in-house IT department. Accessory costs include in this case eight chargers. (Jauernig)

Secondly, the analysis of the gained productivity and accuracy is presented. Annually viewed savings will be made through increased productivity of 17 per cent, which signifies monetary savings of €51, 763€ per annum. Savings related to accuracy are almost three times higher and this highly depends on the error rate, Picks/Hour and the error reduction. Consequently, the coherence between these factors and the amount of savings is quite elastic. That means small changes, especially in error rate, causing great changes in the total savings. To sum up, overall savings, when using Pick-by-Voice instead MDC, are about €212, 000 per annum, which leads to an amortization of 5. 6 months. (Jauernig)

Thirdly, the elimination of evidences, receipts and the organization of re-entering into the data entry system are explained. Cumulating the savings from eliminated papers including printing and all associated costs, in relation to the investment, the savings are approximately 10 per cent of the capital which was invested for the entire solution. Due to the fact that re-entering is

not needed anymore, two job positions based on a €15 hourly wage can be released. With the additionally saved €56, 250, an overall saving of €277, 232 is reached and leading to an amortization of only 4.3 months. (Jauernig)

Figure 8: ROI Calculation Dictulus (Jauernig)

Here is another breath example for the ROI. In this example I will compare the Pick by scan with the Pick by Voice method.

Table 3: Pick-by-scan vs Pick-by-Voice (Jauernig)

Criteria	Unit	Pick by scan	Pick by voice
Number of picks per Order Picker	pcs.	10	9
Positions per Order Picker/Hour	pcs./hr	120	140
Hours per day	hrs/day	8.0	8.0
Positions per day (total)	pcs.	9,600	10,080
Error rate	%	0.400	0.050
Errors per day	pcs./day	38.4	5.0
Working days per year	days/year	250	250
Errors per year	pcs./year	9,600	1,260

Based on the data above, the calculation of the ROI for implementing both methods is as follows: The average wage per order picker is per year € 30, 000, and each error causes costs of €25. The gain in productivity is one order picker per year, which means €30, 000, and the improved order picking quality leads to (9, 600 errors – 1, 260 errors) x €25 = €208, 500 savings. The total savings per year result in savings of €238, 500 whereas the system implementation costs for nine employees aggregate to approximately €120, 000. In terms of the return on investment, the system is amortized in approximately six months. Here are not considered additional savings since Access Points and Server already exist. Also, furthermore savings, for example, referring to the elimination of paperwork, savings in training, customer satisfaction were not taken into account.

The picture below illustrates an overall comparison between pick by ticket, pick by scan, pick by voice, pick by light, and pick by weight;

Table 4: Picking methods comparison (Jauernig)

Criteria	Pick by ticket	Pick by scan	Pick by voice	Pick by light	Pick by weight
Investment	Low	Very High	High	High	Low
Productivity (Picks/Hour)	Medium	Good	Good	Very Good	Good
Hands-free operation	Low	Low	Very Good	Good	Good
Eyes-free operation	Low	Low	Very Good	Good	Good
Identifying invetory location	Text, Digits	Text, Digits	Voice	Light	Digits, Light
Withdrawl confirmation	None	Keys	Voice	Keys	Keys, Automatically
Accuracy	Low/Medium	High	Very High	Very High	Very High
Training	Medium	High	Low	Low	Low
Costs for scalibility (additional inventory locations)	Low	Low	Low	High	Low
Costs for scalibility (additional order pickers)	Low	High	High	Low	Medium
Cost increasing caused by:	Picking	Picking	Picking	Items	Picking
Productivity (Picks/Hour per Order Picker)	70	120	140	220	n.a.
Accuracy (Error rate in % when withdrawl)[1]	0.875%	0.400%	0.050%	0.250%	n.a.

[1]Source: Dematic GmbH & Co. KG

Henry Schein Inc. picks with voice

At Henry Schein Inc., customer satisfaction, accurate order delivery, picking, packing and distribution processes were enhanced. Therefore, the manual

paper system was substituted by voice picking technology in different distribution centers with a daily shipment of 60, 000 boxes. (Henry Schein Inc., 2008)

The installed solution was customized so it even provided the picker with expiration dates, which is crucial for healthcare product distributor. The picking accuracy was increased by 12 per cent and productivity has been approved by 8 per cent. Additional functions enabled the supervisor to track and communicate any product changes for a specific order. Training time was significantly reduced from weeks to days. (Henry Schein Inc., 2008)

The picture below shows clearly the advancement of Henry Schein's picking accuracy comparing years 2007 with 2008;
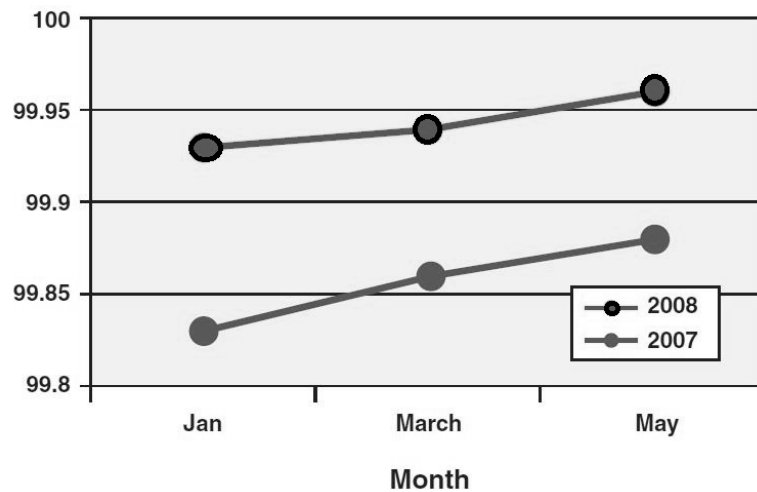

Figure 9: Progress of Picking Accuracy for Henry Schein Warehouse 2007-2008 (Henry Schein Inc., 2008)

4.2 Pick-by-Vision

Due to the early stage of this system, it is hard to find empirical evidence for its functionality. However, DHL ran a pilot testing; involving ten order pickers equipped with, as it was described the theoretical part, HMD. The test has been lasting for three weeks, with more than 20, 000 items picked and more than 9, 000 orders fulfilled.

Previously, picking was a combination of handheld scanners and a pick list. The new system displays in front of the pickers' eyes the task and the place

where to place the picked item in the trolley, which leads to higher accuracy and efficiency.

All in all, it can be said that it increased the performance and the users have accepted it well. The picture below summarizes the pilot-test-run and its results.
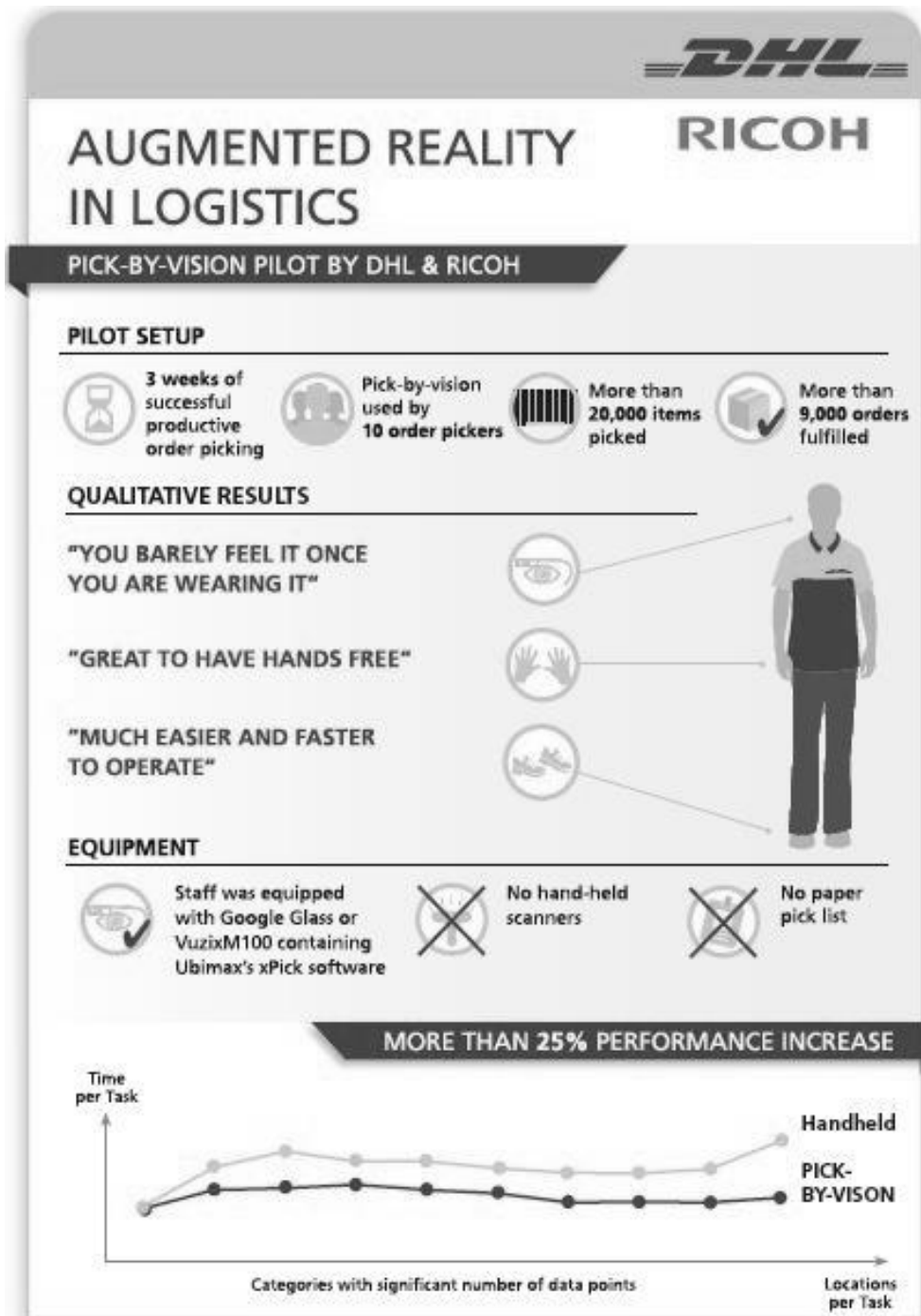

Figure 10: Pick-by-Vision DHL test run (DHL, 2015)

4.3 Radio Frequency Identification

In the upcoming paragraphs, I will explain the use of RFID in completely different industries and especially its benefits. I will discuss four industries: apparel, automotive, healthcare and pharmaceutical and logistics. Section 4 will give the fundamental empirical studies in each of these industries relating RFID.

Apparel Industry – 200 million RFID labels were used in 2009 in apparel and laundry companies. Here are some process improvements initiatives (Palevich, 2012, pp. 52-53):

- Companies, which have been using RFID, recorded an increase of sales of 14 per cent. This increase highly depends on the stock availability and visibility. Having a big number of items lead to lose overview where items are located at the moment, which leads further to customer's thinking of a not available item.
- Since accuracy and pace of processes increased, labor cost can be reduced by 30 per cent because less people are needed.
- Due to the fact that more atomization takes place, fewer people are needed, hence fewer mistakes have been doing and consequently an increase by 27 per cent of inventory accuracy can be recorded. Inventory's accuracy increased to 98 per cent and more.
- The system produces a 99 per cent visibility to the supply chain, which increases service level, company performance and allows the inventory to decrease by 15 per cent owing to faster receiving and better planning in cross-docking received products due to better visibility.

A few different metrics to measure improvement according to Palevich (2012, pp. 53-54):

- It simplicities inventory replenishment within minutes after sales, improves inventory accuracy and ensures availability of stock on selling floor.

- Cycle counting is enormously improved because RFID tags do not require line-of-sight and as one American Apparel company stated, it takes only 15 hours to count instead of 120.

- Another company confirmed the statement by stating that their cycle counting time decreased by 96 per cent since scanning with RFID. So 53 hours were required to count 100, 000 items, which is now done by 2. Averagely 209 items can be scanned with UPC in one hour, whereas with RFID 4, 767 can be counted in one hour. This company switched from UPC to RFID and can count the inventory now 26 times over the previous UPC method.

- Resultantly a high reduction in man-hour for restocking means an increase in man-hour for customer services. Increased efficiencies come from increased in-stock position and shelf-level accuracy, better backroom replenishment, response time enhancement of 50 per cent, reduced excess product/safety stock inventory by 20 per cent, container fleet reduction also by 20 per cent, delivery time's reliability development up to 90 per cent, elimination or reduction to a minimum of product theft and elimination of the ancient 10 to 15 per cent human error rate caused by wrongly entered and captured data.

A national department store, with an annual sale of $3. 47 billion, 68 retail outlets and misplaced goods/ out-of-stocks of 5 per cent, experienced high costs due to these out-of-stock and misplaced items. RFID implementation managed to automate inventory processes, improve inventory management, and increase inventory availability for customers and increase sales. Restocking was now ensured through the immediate inventory on shelves visibility. Overall inventory was more visible, stock outs reduced, and lost sales mitigated due to lost items. (Motorola Solutions, 2012)

This means in numbers, according to Motorola Solutions (2012):

- Misplaced goods and stock outs were reduced by 4 per cent
- Sales increase by $34. 7 million
- Better forecasting, higher visibility and accuracy led to reduced safety stocks and savings of $3. 1 million.

- Theft reduction generated $2. 3 million in savings
- Improved customer satisfaction
- ROI < on year

Automotive Industry – losing or misplacing critical containers in this industry can lead to massive costs. (Palevich, 2012, p. 55) If container of parts or other critical items are not available, epecially at manufacturing sites, substitutable items have to be acquired to ensure the operation of manufacturing. Due to these circumstances an estimated loss per year reaches almost $750 million, stated Bill Hoffman, Industry Expert (Xerafy, 2010). Hence, location, content, MSDS, and more data need to be stored accurately to solve this problem. Consequently, a good solution offers RFID instead of UPC. As previously explained, it provides the functions recently enumerated to solve the problem. That is the reason why RFID could substitute UPC in this industry completely. (Palevich, 2012, p. 55)

Automotive manufacturer's assembly line processes are highly advanced to reduce waste and inefficiencies. RFID enables them to sophisticate their process automation in relation to distributing and managing materials. Everything can be managed and monitored, from supplies to MRO supplies to tools and containers, depending on the assembly lines' level of lean principles. (Xerafy, 2010)

This means for automotive supplier that the pressure, to be more efficient, increased on factors as time, cost, productivity and coherent their margins. RFID supports, for example, asset management using reusable container tracking, item level tool tacking, and even equipment traceability. (Xerafy, 2010)

So since accurate and real-time visibility is possible in the automotive manufacturing supply chain, unneeded repurchases of lost items that are not lost is mitigated. The tracking ability to view the moves from each station, process or department is essential and adds value by providing information on where the container is located and possibilities to revise data. (Xerafy, 2010)

Especially for companies that working on a JIT and JIT basis identified that that container management is crucial to be enhanced due to its high potential in cost savings. Consequently, an intelligent container management solution could reduce costs significantly. (7iD TECHNOLOGIES GMBH)

The following case reveals that the use of RFID varies broadly. In this case, the RFID readers are attached to the forklift.

The case company is a full-service-logistics-provider for Daimler Motor Company located in Bremen, Germany. The company has to meet the just-in-time needs of the components, and 16 forklifts with RFID readers are able to capture 16, 000 storage bins. All items will be delivered directly to the assembly line. The items are stocked in a high rack warehouse eight racks high and with RFID transponders can be easily identified despite greater distances. The UHF-RFID readers were installed/ attached to the forklifts as the picture below shows. (ident, 2013)

Figure 11: RFID reader's position on a forklift (ident, 2013)

A North American transmission manufacturing plant has been saving $2 million per year after installing RFID tool management system. This management system is using LF and HF RFID technology implanted into tool holders. After upgrading transmission processing machines to electronic, read information such as cycle count, size, service data and other 15 parameters were able to record. The automatic system proved to be dependable, repeatable and cost-effective. It was able to reduce the number of broken tools by 75 per cent and tool costs reduction was roughly $1 million per year. Additionally, tool utilization enhancements over 25 per cent by automatic tool tracking were achieved,

which saved approximately $800, 000 per year. Employees' stress was also reduced, but it might not be possible to measure this type of benefit. (Xerafy, 2010)

The comparison below shows the detailed overall savings resulting from the automated RFID tracking implementation.

MANUAL TRACKING

Broken Tools
- Quantity: 175/year
- Down Time: 10 min
- Down Time Cost: $700/min

Broken Tool Impact: $1.225M

Tool Utilization
- Utilization: ← 65%
- New Tools: → 2500/year
- Lost Usage: $590,000
- Tool Setters: 8
- Tool Setter Salary: $600,000

Tool Utility Total: $1.19M

Total Cost: $2.42M

AUTOMATIC RFID TRACKING

Broken Tools
- Quantity: 20/year
- Down Time: 10 min
- Down Time Cost: $700/min

Broken Tool Impact: $140,000

Tool Utilization
- Utilization: ← 92%
- New Tools: ← 1700/year
- Lost Usage: $91,800
- Tool Setters: 4
- Tool Setter Salary: $300,00

Total: $391,000

Total Cost: $0.53M

Figure 12: Manual tracking vs Automatic RFID Tracking (Xerafy, 2010)

Healthcare and Pharmaceutical Industry – the increased need for RFID is caused by patients' intense need of just-in-time medications and care. The use of RFID can bring significant savings up to $2. 6 billion yearly. Additionally, the supply chain visibility increases as well as the collaborative way to share demand information with partners. This is very important for medications that are critical for clinics, pharmacies or hospitals. One of the most important improvements has been reached by the better Track and Trace techniques. According to the data RFID provides, for example, correct delivery, accurate delivery timing, and location, helps the staff in receiving departments to be prepared for receiving and at each point the title of ownership will be identified to reduce product theft. (Palevich, 2012, pp. 55-56)

Logistics Industry – Nowadays RFID is broadly used in logistics and transportation companies to reach almost 100 per cent shipping, receiving and order accuracy, stock accuracy of 99.5 per cent, 30 per cent faster order processing and reduction of labor costs. (Motorola Solutions, Inc., 2011), According to Palevich (2012, p. 56) great advantages of RFID in this industry come through sensors which provide very important information, such as:

- Accurate temperature measurements to reduce spoilage of perishables
- Precise humidity measurement, because e.g. the transportation of paper products requires a dry environment
- Special cases as bacteria e.g. need to be transported in a dark environment and the sensors can measure how much light the product was exposed to.
- Particular products can be damaged by high vibrations, which can be determined/ measured with the sensor.

"Overall, (RFID) sensor data has many uses for the food industry. Chemical-biological and temperature sensors are used to monitor food supply and food recalls – from tracking whether a building that houses food has vibrated to knowing exactly when a container of lettuce will go bad" Richard MacManus, Editor-in-Chief, Readwriteweb "Sensor & RFID apps for the future" May, 2010 (Motorola Solutions, Inc., 2011)

The bullwhip effect will be reduced by the use of RFID. The bullwhip effect is the unknown and fluctuating demand in the supply chain from one link to another, which causes, for example, higher safety stock in the end. This can be avoided or strongly mitigated by sharing, through RFID, information and collaborations with suppliers. (Palevich, 2012, p. 57)

Replenishment Policies are the policies concerning the decision-making of how often and how big the arriving orders will be. The order size is also defined by the EOQ policy or minimum inventory policies of the supplier or distributor. Higher transparency of item-level for trading partners through RFID enables increased inventory performance. (Palevich, 2012, p. 57)

However, RFID can also be used for totally different purposes. For example, in the **Gaming Industry** where RFID serves data such as: average bet per table, shows high and low wagers, alerting manager if a customer has a run. Also, in **Jewelry's Management Industry** RFID finds its use. In this industry e.g. inventory counts can be improved by 90 to 96 per cent. (Palevich, 2012, p. 58)

The table below shows barcodes versus radio frequency identification based on twelve main criteria.

A Dozen Points of Comparison		
	BAR CODES	**RFID**
Technology	Optical	Radio frequency
Line of Sight	Required	Not required
Read Rates	Slow – one at a time	Fast – up to 1,000 in a single pass
Read Range	Inches to a few feet	Tens to hundreds of feet
Memory Capabilities	Static – read-only and limited data capacity	Dynamic – high capacity; reads, writes, updates, triggers other actions
Durability	Exposed – risk of wear and tear or damage during handling	Better protected, can be encased, withstands harsh environments
Service Life	Unlimited, subject to degradation	Up to 10 years
Security	Low – easily copied or faked	High – encryption is harder to replicate
Interference	May be subject to obstruction from dirt or damage from handling	Metal and liquids can interfere with some frequencies
Reusability	No	Yes
Cost	Fractions of a penny to a few cents	Up to $50
Human Labor	Required – high	For handheld readers – moderate Not required for fixed readers

Table 5: Barcode vs RFID (Russel, 2010)

Since the world is recovering from the recession, companies emphasize maximizing their supply chain efficiency to be prepared for economically good and bad times. Especially in logistics, and transportation it is very important to reduce cost, improve services, increase efficiency and ROI from the beginning to the end of the supply chain. *"Increased supply chain visibility based on RFID reads could give companies a better view of when inventory problems might be arising, allowing them to take earlier action that might relieve the need for (and cost of) expediting freight."* – Supply Chain Digest Article, April 2009 (Motorola Solutions, Inc., 2011). More and more companies are using

RFID to create better global supply chain visibility and operations. (Motorola Solutions, Inc., 2011)

According to Palevich (2012, p. 46), the following improvements can be generally achieved by RF in a warehouse:

- 28 per cent more units handled per man-hour, which increases the performance and accuracy in order picking
- Receiving process enhancement of 50 per cent
- 18 per cent decreased cost for each unit handled
- Disclosing location of each product
- A 99. 95 per cent rate in picking accuracy and better customer service

4.4 Warehouse Management System

The following case company is world's market leader in high-performance computing, visualization and management of complex data. In 2002 it generated over $1 billion revenue, inventoried more than 2, 500 items in a 125, 000 square foot warehouse and distribution center. The company was still operating with manual data entry systems, and warehouse operators had to search for items for hours. (Technology Marketing Corporation, 2004)

In order to mitigate or avoid these inefficiencies, amongst others, the existing E-Business Suite was expanded with a Warehouse Management System. Additional barcode scanners and system were integrated as well as Mobile Wireless Application Server (MWAS) which provided a direct link between the scanners and the WMS. Hence, the workers could perform transactions directly from the shop floor. (Technology Marketing Corporation, 2004)

For the entire project, a 12-month ROI was estimated and key metrics established to measure efficiencies such as labor savings, inventory depreciation reduction, total inventory reduction, and reduction in warehouse space. (Technology Marketing Corporation, 2004)

Of these metrics, the ROI was the most significant due to its achievement within six months instead of 12. All other metrics were exceeded or, at least,

met. Transaction volume remained unchanged but with less staff hours, data accuracy was improved, amount of lost items reduced, and the company realized a high payback with a drop of 82 per cent in inventory depreciations. Improved purchase planning while maintaining full production capacity made sure that items are available at any time, and less warehouse space is required. (Technology Marketing Corporation, 2004)

With a WMS, savings in different categories can be achieved. Savings, according to Palevich's categorization in Lean and Green Savings, achieved by WMS can be as follows.

Therefore, a 600.000 square feet warehouse would need approximately 200 workers, but with the reduction of 40 per cent in warehouse labor hours only approximately 125 workers are needed. Consequently, $18 per hour plus benefits of 25 per cent, the total hourly rate is $22. 50. Thus, 250 yearly working days, each working day comprised 8 hours. Consequently, the result of 250 x 8 x $22. 50 x 75 people is $3, 375, 000 labor savings per year. After reducing the inventory by 2, 7 per cent of$217 million inventory lead to savings about $6 million. A reduction by 26. 6 per cent in carrying costs will lead to approximately $1. 6 million (26. 6 per cent x $6 million) savings. The freed-up cost of capital is 0. 02 x $6 million, which leads to an inventory saving of about $120, 000. All the savings add up to approximately $5, 095, 000. Due to improved space utilization (25 per cent x 600, 000 sq. ft. = 150, 000 sq. ft.) and thus a shortage in use of electricity the Green Savings add up to savings in utilities of $85, 755 yearly. The yearly overall savings are so far cumulative $5, 180, 755. (Palevich, 2012, pp. 37-38)

The following case study will show the use of all discussed topics, pick by voice, RFID and coherent WMS, in one.

The case related to a frozen and chilled foods distributor. These companies are facing the challenges of delivering to the right place, at the right time, and temperature and often have short lead times. The case company has over 4, 000 SKUs of frozen and chilled foods consolidated for deliveries to the main supermarket regional DCs in the UK. More than 1. 5 million pallets are handled, with a market value in excess of 1 million pounds and 260, 000 orders

yearly. The company pursues to shorten production runs, have lower stocks for manufacturers and retailers, and maintain shorter lead times in its supply chain. Additionally developing shared user network leads to lower the cost base. Thus, the provision of greater on-line links between the supplier and retailer and working together in partnership, leads to fasten stock replenishments. (Emmett, 2005, pp. 130-131)

Therefore, IT controls all in-store and traffic operations. Via EDI, orders are received from customers and retailers, additionally customers have a 24 hours live-access to stocks and movements. All 140 of the company's vehicles use a communication system and are temperature-controlled with radio frequency. (Emmett, 2005, p. 130)

The company adopted the following technology advances: online order receipt and progress, live order fulfilment reports, livestock information for retailer and supplier as well as product traceability with audit trail. For the future, it is planning to extend the use of radio frequency identification from the vehicles to the products utilizing the system for units that can be returned. The company, which has been operating a paper based system, is highly interested in RFID because it delivers more benefits than barcoding but is yet too costly. (Emmett, 2005, p. 131)

Pick lists, clipboards and pencils belong now to the past and are substituted by voice picking. "*Human dialogue is the easiest and most productive way to keep hands free,*" explains Keith Boardall, Group Managing Director. Truck-mounted or hand-held RF terminals with keyboards, scanners or RFID tags were removed by the combination of using pick by voice with the WMS. Since pickers are operating hands-free, they are able to carry more boxes, which leads to greater productivity. Another benefit is that the picker logs on to the system verbally and the shift manager can do so as well. However, when the shift manager's logging on process is discrete; he can listen to the picker's dialogue. This enhances e.g. new picker's training. (Emmett, 2005, p. 131)

5   CONCLUSION

Operating a warehouse in an effective way is crucial because a warehouse takes an important role in the overall supply chain. Therefore, reducing costs in warehouse operations can be the key to overtake competitors and thus secure and enhance the market position. There is no one-fit-all solution in any industry but with a combination of all three systems almost every faced challenge by warehousing companies can be solved. Nonetheless, the single systems are applicable to each industry and significant results can even be achieved by the single solution implementation.

Pick-by-Voice increases tremendously productivity, accuracy, and efficiency, saves costs, heightens employees' and especially customers' satisfaction and finally has a fast ROI. RFID highly fastens cycle counts, increases inventory accuracy, allows item tracking, reduces labor costs extremely, enables high variety in use, and high ROI. WMS implementation will lead to real-time stock visibility, traceability and interchange with workers, customers or partners. Also, accurate stock, automatic replenishments, data visibility and increases productivity, are positive results after the implementation of a WMS.

As clearly seen all the solutions have common parameters of benefits. Hence, by implementing the solutions combined, many synergies will be created and hence greatly higher results will be achieved. For example, the double checking between the system and RF reduces shipping errors by 80 per cent. (Palevich, 2012, p. 37) The earlier the implementation of a solution takes place, e.g. which enhances productivity, the better and the more can be saved. However, warehouse operating companies should always be up to date because e.g. pick by voice or pick by vision cannot only increase productivity but also employee's safety, customer satisfaction and increase the ease of co-operation. Referring to picking; the more picks a warehouse has to make, the more efficient will be the deployment of advanced picking methods such as voiced directed picking. Thus, the more automated companies are working the smaller is the number of manual mistakes for example data entry. Consequently, for example, a WMS should not be installed singly but it should be linked to ERP systems, among others, to receive all advantages. Neverthe-

less, of course first of all the monetary resources have to be available to do initial investments.

However, these systems have to be treated with caution. Since they are controlled automatically, they have to run without any errors 24 hours constantly. Compatibility issues may cause high costs of implementation. One of the greatest risks, especially in voice picking, is that the people are relying completely on technology, becoming comfortable with the new solutions and are soon unable to fulfil the job without technical help. This system also cannot control the amount of picked goods.

As described in the chapter 3.2.2.4 there is no standard set yet for the entire world's frequencies, which leads to multiple scans. Consequently, the goods and the worker are the electromagnetic radiation burden exposed. RFID is facing also problems e.g. when it scans metals. For companies, it might be a problem if RFID tags are not disabled after sales and unauthorized people can read out data. Accordingly, for all parties data privacy is at risk – as for consumer, employee or entrepreneur.

However, for all new investments companies have to balance the pros and cons. A WMS for example requires high initial investments and many warehouses have to be rearranged according to the WMS to ensure all processes operate well. Compatibility issues can be arising. For example, if a WMS is chosen and a few years later additional technology advancement shall be implemented this advancement may not be compatible with the WMS or not fully compatible so that not 100 per cent of its features can be used.

The reliability of used sources was highly important for me and caused different challenges, especially for the empirical part because the research was done without cooperating with a company. Challenges were e.g. to determine from whom the case is, the solution provider or the client and if it is influenced somehow. As a result, I had to delete, after reflection, many paragraphs because the sources did not seem reliable and independent. I left on purpose one case of a solution provider (Xerafy). Nonetheless, for this particular case, is the solution provider different (Balluff). Hence, Xerafy sways to and fro whether they promote the Balluff's solution or paint it black.

In the future, the RFID's use will increase because prices for printed electronics are decreasing. It can be adopted in many different ways. Accordingly the technology's use and its different functions increases e.g. combining RFID with NFC (Near Field Communication), and is estimated to grow yearly 25 per cent, as the industry estimates. (Löhle, 2013, p. 64) Regarding the picking systems, the solutions move more and more away from paper and will be combined with scanning and electronically developed picking solutions. Especially pick-by-vision will have a great future, because it includes pick-by-voice, additionally the smart glasses and can be equipped with an additional camera.

Finding out which picking system is best requires more research. More criteria and more comparison should be done because my research, referring to picking methods, compares often with paper based picking methods and thus is slightly one-sided. Additionally, other picking methods can lead to even better results, but were not taken into account. Relating to RFID the study was conducted in a similar way and the advantages of barcoding were not seen as relevant but in some cases barcoding is ahead of RFID. The study ignores also all kind of complications that can occur at the beginning of implementation, e.g. WMS, or future complications when combining solutions with existing ones. Also, the consequences for a company in case of a system crash or breakdown of a solution, e.g. pick-by-voice, were not considered in the study and as well as the training costs for a newly implemented system were not taken into account. Therefore the cost for the training has to be determined and also cost occurring after implementation.

6 LIST OF FIGURES

7 LIST OF TABLES

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9 APPENDICES

Appendix 1: The types of typical costs within a warehouse

The types of typical costs within a warehouse (According to Richards)				
Space Costs	**Fixed Costs**	**Variable Costs**	**Overhead Costs**	**Miscellaneous Costs**
- racking depreciation - insurance - rates/ government taxes - utility & telecoms costs - fixtures & fittings depreciation - repairs & maintenance - rent/leasing of land & building & depreciation - cleaning, security & other building equipment depreciation - refrigeration plant depreciation - waste disposal	●**Direct Labour Costs (operators)** - wages + on-costs - personnel insurance - safety wear - welfare - training ●**Indirect Labour Costs (Management + Supervisors &** - wages + on-costs insurance - safety wear - welfare - training ●**Equipment costs** - depreciation/lease costs/ rental costs	●**Labour Costs** - overtime & bonuses ●**Equipment Costs** - running costs as fuel, lubricants etc. - packaging, pallets & stretch wrap	●**Management, Finance, HR, IT & Administration** - salaries, on -cost plus benefits etc. - company cars & running costs - IT hardware & software - office equipment, furniture depreciation/ rental/lease costs ●**Sales & Marketing in 3PLs** - salaries, on -cost plus benefits etc. - company cars & running costs - marketing spend	- communication costs - postage - bank charges and interest payments - funding costs/costs of finance - insurance - audit fees - legal and professional fees